



Study on distribution coefficient of bromide ions from aqueous solution on ion exchange resins Indion-850, Indion-860 and Indion FF-IP

Pravin Singare^{*a}, Ram Lokhande^b, Vinayak Patil^b, Tirtha Prabhavalkar^b and Santoshi Tiwari^b

^a Department of Chemistry, Bhavan's College, Munshi Nagar, Andheri, Mumbai, PIN-400 058, India

^b Department of Chemistry, University of Mumbai, Vidyanagari, Kalina, Santacruz, Mumbai, PIN-400 098, India

*Corresponding author at: Department of Chemistry, Bhavan's College, Munshi Nagar, Andheri, Mumbai, PIN-400 058, India. Tel: +91.222.6256451; fax: +91.222.6256453. E-mail address: pravinsingare@vsnl.net (P.U. Singare).

ARTICLE INFORMATION

Received: 8 February 2010

Received in revised form: 15 March 2010

Accepted: 17 March 2010

Online: 31 March 2010

KEYWORDS

Ion exchange resin
Distribution Coefficient
Indion-850
Indion-860
Indion FF-IP

ABSTRACT

The ion exchange resin Indion-850, Indion-860 and Indion FF-IP, in bromide form were equilibrated separately with the labeled radioactive bromide ion solution of different concentrations varying from 0.005 M to 0.100 M in the temperature range of 25.0 °C to 45.0 °C. The K_d values of bromide ions were observed to be high for Indion-850 and least for Indion 860, while Indion FF-IP shows intermediate K_d values under identical experimental conditions. The difference in K_d values of bromide ions for the three resins is mainly because of the swelling pressure which depends on their water holding capacities.

1. Introduction

There are a number of liquid processes and waste streams at nuclear power plants, fuel reprocessing plants and nuclear research centers that require treatment for removal of radioactive contaminants. One of the most common treatment methods for such aqueous streams is the use of ion exchange, which is a well developed technique that has been employed for many years in nuclear industries [1,2]. The ion exchange process is very effective at transferring the radioactive content of a large volume of liquid into a small volume of solid. Efforts to develop new ion exchangers for specific applications are continuing. In spite of their advanced stage of development, various aspects of ion exchange technologies have been continuously studied to improve the efficiency and economy of their application in radioactive waste management. The selection of an appropriate ion exchange material for the liquid radioactive waste treatment is possible on the basis of information provided by the manufacturer. However since the selection of the appropriate ion exchange material depends on the needs of the system, it is expected that the data obtained from the actual experimental trials will prove to be more helpful. Generally the selected ion exchange materials must be compatible with the chemical nature of the radioactive liquid waste type and the concentration of the ionic species present as well as the operating parameters notably temperature. Also while designing an ion exchange processing system it is desirable to have adequate knowledge of the distribution coefficient values of the ion exchange resin towards different ions present in radioactive liquid waste. These distribution coefficients are very important parameter for environmental impact assessment on the disposal of radioactive waste arising from research institutes [3].

Although there are different alternative methods available to find the distribution coefficient values, radioactive isotopic technique is expected to be the most appropriate method as it offers several advantages such as high detection sensitivity, capability of in-situ detection, and physico-chemical compatibility with the material under study [4-8].

Attempts were made by the previous researchers to study the concentration and temperature effect on cation exchange systems for computing the distribution coefficient values [9-15]. However very little work was done to study the distribution coefficient values in anion exchange systems [16]. Therefore, in the present investigation, radioactive isotopic technique was applied to study the factors affecting the distribution coefficient of bromide ions on anion exchange resins Indion-850, Indion-860 and Indion FF-IP.

2. Experimental

The ion exchange resins Indion-850, Indion-860 and Indion FF-IP as supplied by the manufacturer (Ion Exchange India Ltd., India) were in chloride form. Details regarding the properties of the resins used are given in Table 1.

The resins were converted in bromide form by eluting with 10% KBr solution in a conditioning column. 1.000 g (*m*) of conditioned resins in bromide form was equilibrated with 250 mL (*V*) of labeled radioactive bromide ion solution (0.005 M) under continuous and uniform mechanical stirring. The solution was uniformly stirred using the mechanical stirrer for 3 hrs. at a constant temperature of 25.0 °C so as to attain equilibrium.

The ion-isotopic exchange reaction taking place can be represented as follows:

Table 1. Properties of ion exchange resins.

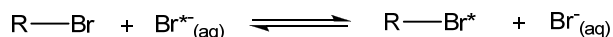
Ion exchange resin	Type/functional group/ionic form	Particle size, mm	Moisture content, %	Operating pH	Maximum operating temp., °C	Total exchange capacity, meq/mL
Indion-850	Weakly basic macroporous crosslinked polystyrene resin in Cl ⁻ form having -N ⁺ R ₂ functional group	0.3-1.2	49	0-7	60	1.50
Indion-860	Weakly basic macroporous crosslinked polystyrene resin in Cl ⁻ form having -N ⁺ R ₂ functional group	0.3-1.2	54	0-7	60	1.40
Indion FF-IP (Type-1)	Strongly basic isoporous cross linked polystyrene resin in Cl ⁻ form having -N ⁺ R ₃ functional group	0.3-1.2	51	0-14	60	1.20

Table 2. Effect of ionic concentration on bromide ion distribution coefficients. Temperature = 25.0 °C, amount of ion exchange resin in bromide form = 1.000 g, volume of labeled radioactive bromide ion solution = 250 mL.

Concentration of labeled bromide ion solution, (M)	Amount of bromide ions in 250 mL solution, (mmol)	Log K _d		
		Indion-850	Indion FF-IP	Indion-860
0.005	1.25	4.00	3.38	3.00
0.010	2.50	4.23	3.51	3.08
0.020	5.00	4.49	3.67	3.19
0.040	10.00	4.65	3.78	3.34
0.100	25.00	5.08	3.95	3.50

Table 3. Effect of temperature on bromide ion distribution coefficients. Concentration of labeled radioactive bromide ion solution = 0.005 M, volume of labeled radioactive bromide ion solution = 250 mL, amount of bromide ions in 250 mL solution = 1.25 mmol, amount of ion exchange resin in bromide form = 1.000 g.

Temperature, °C	Log K _d		
	Indion-850	Indion FF-IP	Indion-860
25.0	4.00	3.38	3.00
30.0	3.87	3.20	2.91
35.0	3.65	3.05	2.78
40.0	3.49	2.93	2.62
45.0	3.28	2.81	2.54



Where Br^{*}_(aq) represent aqueous bromide ion solution labeled with radioactive isotope ⁸²Br.

The initial activity (A_i) and final activity (A_f) in counts per minute (cpm) of the labeled solution was measured on γ-ray spectrometer having NaI(Tl) scintillation detector. From the knowledge of A_i and A_f, the K_d value was calculated by the equation

$$K_d = \left[\frac{(A_i - A_f)}{A_f} \right] \times \frac{V}{m} \quad (1)$$

The experimental sets were repeated in the same manner by increasing the bromide ion concentrations up to 0.100 M and the temperature up to 45.0 °C. The K_d values for different sets were calculated by Eq. (1). The ⁸²Br isotope used in the present experimental work was an aqueous solution of ammonium bromide in dilute ammonium hydroxide having activity 5 mCi, γ-energy 0.55 MeV, and t_{1/2} 36 hrs [17].

3. Results and Discussion

In the present research work, the ion exchange resin in bromide form was equilibrated for 3 hrs. with labeled bromide ion solution of known initial activity. From the results of previous work [4-8,18-24]; it was observed that this duration time was sufficient to attain equilibrium. Due to ion isotopic exchange reactions taking place the activity of the aqueous solution decreases with time. The decrease in activity of the solution was measured after 3 hrs. which represents the final activity exchanged on the resin. From the knowledge of initial and final activities, the K_d values were calculated by Eq. (1), to study the effect of temperature and concentration. Heumann *et al.* [16] in the study of chloride distribution coefficient on strongly basic anion-exchange resin observed that the selectivity coefficient between halide ions increases at higher electrolyte concentrations. Adachi *et al.* [9] observed that the swelling pressure of the resin decreased at higher solute

concentrations resulting in larger distribution coefficient values. The temperature dependence of the distribution coefficient of a cation exchange resin was studied by Shuji *et al.* [11], they observed that the distribution coefficients increased with decreasing temperature. The present experimental results also indicate that the distribution coefficient K_d values of bromide ions for the three resins increase with increasing concentration of bromide ion (Table 2), however with rise in the temperature the same calculated values were found to be lower (Table 3). The distribution coefficient values of bromide ions were observed to be higher for Indion-850 and lower for Indion 860, while Indion FF-IP shows intermediate K_d values under identical experimental conditions (Tables 2 and 3). The difference in distribution coefficient values for the three resins is mainly because of their water holding capacities which affect the swelling pressure. The comparison of bromide ion distribution coefficient values for different ion exchange resins obtained in present investigation with that obtained by other researchers is presented in Table 4. The variation in K_d values of bromide ions with temperature and concentration of ionic solution for the ion exchange resins Indion-850, Indion-860 and Indion FF-IP is graphically represented in Figure 1.

4. Conclusions

In heavy metal removal processes the rate of removal is considered to be an important factor from the practical aspect of reactor design and process optimization [25]. Earlier research was performed to demonstrate the feasibility of biosesin in a continuous system for decontaminating pool water of ⁶⁰Co [26]. It is important here to note that in all of the above decontamination processes, distribution coefficient values plays a very prominent role in deciding the proper selection of resins. The work carried out in the present experiment is a demonstration showing the application of radioactive tracer technique to study the parameters affecting the distribution coefficient. The same technique can be extended further to study the K_d values for various ions in liquid radioactive waste using different ion exchange resins.

Table 4. Comparison of the present data with those of other references.

Authors	Resin used	K _d values of Br ⁻ , (mL.g ⁻¹)
Van Der Walt et al. [13]	Purolite S-950 (H ⁺ form)	< 1.0*
Heumann et al. [16]	AG-1-X10 (F ⁻ form)	100 -1000 **
	Indion-850	10000-120226***
Present data	Indion FF-IP	2399-8913***
	Indion-860	1000-3162***

* 1.000 g of ion exchange resin, equilibrated with 200 mL of 0.1 mmol of Br⁻ ion solution in HCl medium at 20.0 °C.

** 0.500 g of ion exchange resin, equilibrated with 10 mL of 0.5 mmol of Br⁻ ion solution in KF medium ranging up to 10 M at 20.0 °C.

*** 1.000 g of ion exchange resin, equilibrated with 250 mL of 1.25–25 mmol of Br⁻ ion solution in aqueous medium at 25.0 °C.

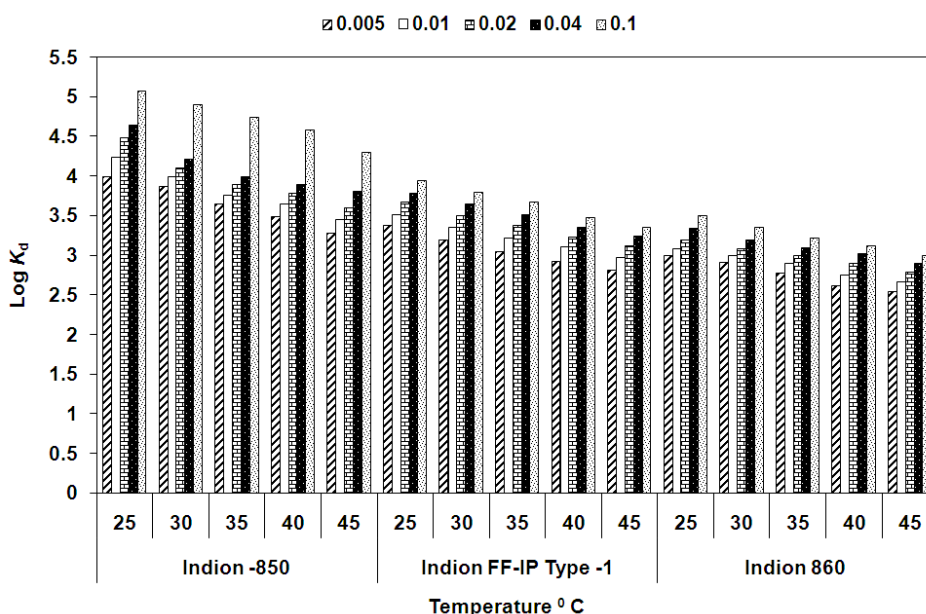


Figure 1. Variation of bromide ion distribution coefficients with bromide concentration and temperature. Amount of ion exchange resin in bromide form = 1.000 g, volume of labeled radioactive bromide ion solution = 250 mL.

The data obtained on K_d value will serve as a very important parameter for environmental impact assessment on the disposal of radioactive waste [3].

References

- International Atomic Energy Agency, Operation and Control of Ion Exchange Processes for Treatment of Radioactive Wastes, Technical Reports Series, No.78, IAEA, Vienna, 1967.
- International Atomic Energy Agency, Treatment of Low- and Intermediate-level Liquid Radioactive Wastes, Technical Reports Series No. 236, IAEA, Vienna, 1984.
- Shin'ichi, T.; Masayoshi, A. *Nippon Genshiryoku Kenkyujo Jaeri*, Data, Code 2001, 102P.
- Lokhande, R. S.; Singare, P. U.; Patil, A. B. *Radiochim. Acta* **2007**, *95*, 111-114.
- Lokhande, R. S.; Singare, P. U.; Kolte, A. R. *Radiochim. Acta* **2007**, *95*, 595-600.
- Lokhande, R. S.; Singare, P. U.; Karthikeyan, P. *Russ. J. Phys. Chem. A* **2007**, *81*, 1768-1773.
- Singare, P. U.; Lokhande, R. S. Patil, A. B. *Radiochim. Acta* **2008**, *96*, 99-104.
- Lokhande, R. S.; Singare, P. U.; Prabhavalkar, T. S. *Russ. J. Phys. Chem. A* **2008**, *82*, 1589-1595.
- Adachi, S.; Mizuno, T.; Matsuno, R. *J. Chromatography A* **1995**, *708*, 177-183.
- Adachi, S.; Watanabe, T.; Kohashi, M. *Agr. Biol. Chem. Tokyo* **1989**, *53*, 3203-3208.
- Shuji, A.; Takashi, M.; Ryuichi, M. *Biosci. Biotech. Bioch.* **1996**, *60*, 338-340.
- Adachi, S.; Matsuno, R. *J. Appl. Glycosci.* **1999**, *46*, 9-14.
- Van Der Walt, T. N.; Coetzee, P. P. *Anal. Bioanal. Chem.* **1996**, *356*, 420-424.
- Strelow, F. W. E. *Solvent Ext. Ion Exc.* **1986**, *4*, 1193-1208.
- Sangurdekar, P. R.; Melo, J. S.; D'Souza, S. F. In Proceedings of Nuclear and Radiochemistry Symposium, Amritsar, India, 2005; pp. 361-362.
- Heumann, K. G.; Baier, K. *Chromatographia* **1982**, *15*, 701-703.
- Sood, D. D. In Proceedings of International Conference on Applications of Radioisotopes and Radiation in Industrial Development, Sood, D.D.; Reddy, A.V.R.; Iyer, S.R.K.; Gangadharan, S.; Singh, G., Eds. BARC: Mumbai, 1998; pp 35-53.
- Lokhande, R. S.; Singare, P. U.; Dole, M. H. *J. Nuc. Radiochem. Sci.* **2006**, *7*, 29-32.
- Lokhande, R. S.; Singare, P. U.; Dole, M. H. *Radiochemistry* **2007**, *49*, 519-522.
- Lokhande, R. S.; Singare, P. U. *Radiochim. Acta* **2007**, *95*, 173-176.
- Lokhande, R. S.; Singare, P. U. *J. Porous Mater.* **2008**, *15*, 253-258.
- Lokhande, R. S.; Singare, P. U.; Patil, V. V. *Radiochemistry* **2008**, *50*, 638-641.
- Lokhande, R. S.; Singare, P. U.; Parab, S. A. *Radiochemistry* **2008**, *50*, 642-644.
- Lokhande, R. S.; Singare, P. U.; Tiwari, S. R. D. *Radiochemistry* **2008**, *50*, 633-637.
- Suh, J. H.; Kim, D.S. *J. Chem. Technol. Biotechnol.* **2000**, *75*, 279-284.
- Sangurdekar, P. R.; Melo, J. S.; D'Souza, S. F.; Pimputkar, D. P., In Proceedings of Nuclear and Radiochemistry Symposium, BARC: Mumbai, 2003; pp 545-546.